Exotic Earthworms on the Ottawa National Forest

Summary of findings from earthworm and botany surveys, 2002-2011

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Introduction

Exotic earthworms are a concern in the upper Great Lakes region that has only recently been discovered (Bohlen et al. 2004). This area (Michigan, Minnesota, and northern Wisconsin) did not have native earthworms prior to European settlement because of the Wisconsinan Glaciation (Fig. 1) which scoured away surface soils and eliminated any native earthworms.

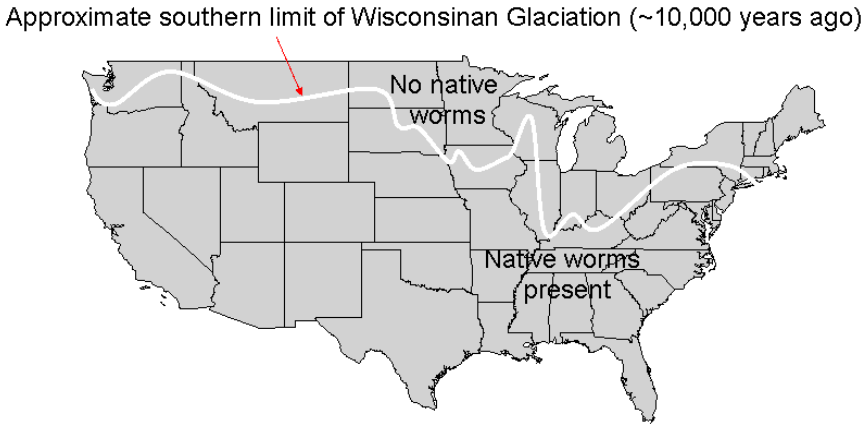

Figure 1. Extent of Wisconsinan Glaciation. No native earthworms existed north of this line.

Since the area was settled by Europeans, earthworms have been introduced back to the region. At least 45 species of earthworms have been introduced into the United States, most from Europe, followed by Asia (Hendrix and Bohlen 2002). Three broad ecological categories of earthworms have been described. Epigeic species are small, pigmented, and live and feed in the duff layer. Endogeic species are medium sized, unpigmented, and live in the surface mineral soil, but can extend up into the duff layer. The final group of species is termed anecic, and they are the large earthworms. They burrow deeply, often vertically, are dorsally pigmented, and feed principally on surface leaf litter (Hale et al. 2005).

Early earthworm introductions were probably from earthworm or egg-containing soil used as ship's ballast or in soil around the roots of potted plants (Tiunov et al. 2006). Subsequent introductions have been from such activities as use of worms for fishing bait and intentional releases for composting (Hendrix and Bohlen 2002). The natural rate of spread is relatively slow: Hale et al. (2005) found that earthworms in Minnesota advanced 20-30 meters in three years. Earthworms can be spread long distances by any activity that moves soil around. Earthworms produce egg cocoons that are very small (slightly bigger than a pin head) and are easily picked up in mud and transported on the tires of vehicles. Therefore, roads have been found to be a major vector in the spread of earthworm cocoons (Dymond et al. 1997).

Earthworm invasions often follow a wave-like successional pathway. The first wave includes species like *Dendrobaena octaedra*, an epigeic species. They can reach high densities but do not appear to substantially impact the duff layer. The second wave is endogeic species such as *Lumbricus rubellus* and *Aporrectodea* spp. These species often do impact the duff layer, frequently completely removing it. Finally, anecic species, such as *L. terrestris* complete the invasion. The early waves tend to facilitate subsequent ones, for instance, endogeic species removing the duff layer facilitates invasion by *L. terrestris*, which prefers mineral soils without a duff layer (Hale et al. 2005).

The ecological impact of the introduction of earthworms into an ecosystem that developed in their absence is currently under investigation, but is potentially large. Northern forests have developed a thick duff layer which stores large amounts of slowly decomposing organic material, as a result of the absence of earthworms. Introduced earthworms eat this duff layer and move the organic material down into the mineral soil. This accelerates the rate of decomposition and nutrient cycling, potentially changing the competitive dynamics of forest vegetation, such as favoring species that require higher concentrations of available nutrients. It also favors plant species that require mineral soil for germination. It disrupts mycorrhizal relationships between plants and fungi, favoring species that are non-mycorrhizal, such as Pennsylvania sedge (*Carex pensylvanica*) (Frelich et al. 2006). The duff is home to certain plant species, such as *Botrychium mormo* (goblin fern), and the loss of the duff is a serious threat to the viability of these species (Gundale 2002, USDA Forest Service 2002).

The Ottawa National Forest has recognized the potential threat posed by exotic earthworms by incorporating direction into the Forest Plan (2006, pages 2-12 – 2-13) designed to help slow the spread of earthworms, particularly in areas that have natural barriers to spread, such as stands isolated by wetlands.

There are currently no known methods for removing earthworms once they are introduced and become established. Earthworms do have a large suite of natural enemies including the cluster fly, *Pollenia rudis;* mites; nematodes; birds; and mammals (moles and rodents), that could offer some control of their populations.

Methods

Three types of surveys have been conducted on the Ottawa National Forest for earthworms. The first was an earthworm-specific survey performed by a contractor in 2003 that surveyed 40 sites. This survey provided the most thorough and accurate quantitative data. The second survey, also earthworm-specific, was performed by Forest Service personnel in 2004 and surveyed 45 sites. The final type of survey is ongoing, qualitative, and consists of visual examinations of stands for earthworms, castings, depleted duff and other signs of earthworm presence while performing botany surveys for vegetation management and other projects. These surveys are performed by both contractors and Forest Service personnel and occurred between 2002 and 2011. Projects for which some earthworm observations were made include the following: Ridge, Rousseau East, Mud Lake, Beaton, Redboat, and Delich land exchange. Observations were also made during surveys for the management indicator species (MIS), cutleaf toothwort, from 2006 through 2011.

The 2003 survey consisted of collecting earthworms in five, 0.25m^2 plots. The five samples consisted of a central plot with four plots 75 ft. away at each of the cardinal points. The leaf litter and duff layers were hand sorted for worms, then a mustard solution was poured on the exposed mineral soil. The mustard water solution irritates the earthworms and forces them to the surface (Paulson-Lawrence and Bowers 2002). Any earthworms found were collected, preserved in 5% formalin, and identified to species (immature specimens were identified to genus). In addition, measurements of the depth of leaf litter and duff were taken. Forty total sites were sampled, 30 were chosen based on different disturbance types (logging, roads, and fishing). The remaining ten sites were in the Sylvania Wilderness to serve as a control because it is one of the few places on the Ottawa that has not had extensive logging and road building, although the area does have a few old roads and does receive heavy fishing pressure. Live bait is not permitted in the Wilderness, so the release of earthworms is less likely there than other places on the Ottawa (USDA Forest Service 2003).

The methods used in 2004 were similar to the 2003 survey but were considerably abbreviated. Only a single sample was collected at each site, and no measurements of litter or duff layers were taken. This method was used more for detecting earthworm presence/absence rather than for determining densities. As a consequence, this year's results were only weakly comparable to the 2003 survey. A total of 45 sites were sampled. The sites were chosen in areas of proposed timber sales and along major roads.

The final type of worm survey is incidental to botanical surveys. Beginning in 2007, noting the presence of earthworms has become a requirement in botany survey contracts, and will continue to be until the distribution of earthworms on the Ottawa is sufficiently understood. Prior to 2007, starting in about 2002-03, Forest Service botanists and contractors, while performing botany surveys, sometimes noted whether earthworms were present in stands. Earthworm presence was inferred from the lack of a duff or litter layer, visible earthworm castings, or finding actual earthworms. These surveys were qualitative, often incomplete, and serve only to indicate the presence or absence of earthworms, but they do give an indication of the scope of earthworm distribution on the Forest.

Results

Between 2002 and 2011, over 1250 stands have been examined and found positive for the presence of invasive earthworms (Fig. 2). Eighty-five stands were examined specifically for earthworms in 2003 and 2004. A total of five earthworm species were found on the Ottawa National Forest in the 2003 earthworm survey (USDA Forest Service 2003). They were *Dendrobaena octaedra* (epigeic), *Lumbricus rubellus* (epi-endogeic), *L. terrestris* (anecic), *Aporrectodea tuberculata* (endogeic), and *Aporrectodea rosea* (endogeic).

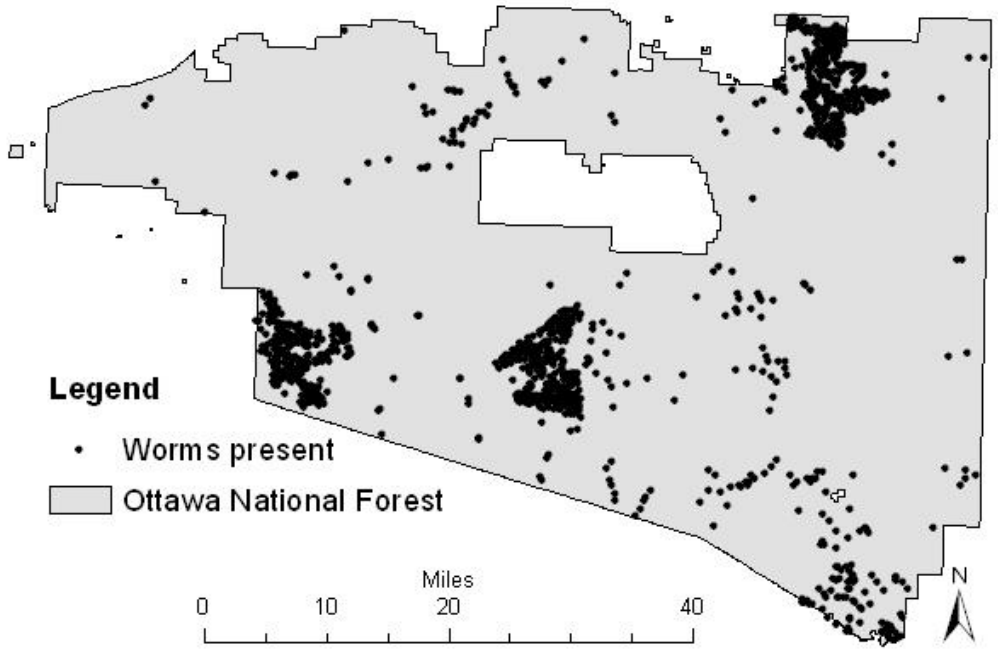

Figure 2. Documented earthworm occurrences on the Ottawa National Forest, 2002-2011.

Outside the Sylvania Wilderness, 30 stands were examined for the presence of earthworms (USDA Forest Service 2003). All were found to have at least one species of invasive earthworm (Table 1).

Table 1. Proportions of stands, outside the Sylvania Wilderness, infested with earthworms during 2003 earthworm survey

Infested stands outside of Sylvania	**%**	**# of stands infested**
Stands with *D. octaedra*	93	28
Stands with *Lumbricus* (*rubellus*, *terrestris*, or both)	83	25
Stands with *Aporrectodea* (*tuberculata*, *rosea*, or both)	53	16
Stands with more 2 or more species	67	20
Stands with 3 or 4 species	47	14

The mean densities of earthworms were 8.99/m^2 for *D. octaedra*, 7.97/m^2 for *Lumbricus* sp., and 2.45/m^2 for *Aporrectodea* sp. The overall mean earthworm density was 19.41/m^2.

Within the Sylvania Wilderness, ten sites were examined and five had earthworms, all *D. octaedra*. Five sites did not have earthworms. The mean density of *D. octaedra* in Sylvania was 4.96/m^2. Duff depth was significantly thicker in the Wilderness compared with the rest of the sites ($p < 0.001$) (USDA Forest Service 2003).

The 2004 earthworm survey sampled 45 sites, emphasizing areas of proposed timber sales (Bluff Divide, Three Corners, and Camp 7), and high use areas such as north of Bergland and along US-45 south of Watersmeet. There were no wilderness sites.

Of the 45 stands examined in the 2004 surveys, 57% (26) were found to have at least one species of earthworm (Table 2). Number of species and densities were much lower than the survey in 2003. Densities of earthworms were 2.47/m^2 for *D. octaedra*, 0.62/m^2 for *Lumbricus* sp., and 0.02/m^2 for *Aporrectodea* spp. The overall mean earthworm density was 3.11/m^2.

Table 2. Proportions of stands infested with earthworms during 2004 survey

Infested stands	**%**	**# of stands infested**
Stands with *D. octaedra*	53	24
Stands with *Lumbricus* (*rubellus*, *terrestris*, or both)	20	9
Stands with *Aporrectodea* (*tuberculata, rosea* or both)	2	1
Stands with more 2 or more species	16	7
Stands with 3 or 4 species	2	1

In MIS surveys, which are conducted exclusively in northern hardwood stands, 100% of 131 stands were found to contain earthworms.

Discussion and Conclusions

Based on the surveys conducted between 2002 and 2011, it can be said that the Ottawa National Forest is generally heavily wormed. The 2003 earthworm survey (USDA Forest Service 2003) found earthworms in virtually every place that was surveyed. Most sites had more than one species indicating that the infestation was fairly advanced. The only place in this survey that was not heavily wormed was the

Sylvania Wilderness, which is the only wilderness on the Ottawa that was never significantly logged or roaded. Both other wildernesses have been logged in the past and the main trail leading into the McCormick Wilderness is heavily wormed (S. Dunlap, *personal observation*). No surveys have been completed in the Sturgeon River Gorge Wilderness but it is likely that it is wormed too. Anecdotal reports from other botany and wildlife surveys in the last 2-3 years note frequent observations of earthworms at sites across the Ottawa.

The 2004 earthworm survey found fewer sites that had earthworms, and far fewer that had more than one species. It is likely that this survey under-represented the true distribution of earthworms for several reasons. The first is that it was performed by Forest Service personnel that were not earthworm experts, whereas the 2003 survey was conducted by a contractor very familiar with earthworm surveys. Second, a single sample was taken at each site. Earthworms are often patchily distributed on a small scale, and a single sample could have missed them if they truly were at a site.

Botany surveys found earthworms in the majority of stands examined. Since these observations are based on visible signs of duff depletion or bare patches of forest soil, it suggests that these invasions are fairly advanced. This is because species like *L. rubellus* and *L. terrestris*, which are not normally pioneering species, are the species primarily responsible for duff and litter depletion. It is probable that many of the stands where earthworms were not found may actually have earthworms such as *D. octaedra* which could be missed because they are small and do not seriously reduce the duff or litter layers. Also, contracted botanists have differing degrees of experience in recognizing worm effects, and are focusing on observing plants, which may result in worm-infested stands not being recorded.

In conclusion, forest management and recreational activities such as road building and maintenance, timber harvest, and off-highway vehicle use all have the potential to further the spread of exotic earthworms. However, they would be accelerating a process already well underway. The long-term consequences of the continued spread of invasive earthworms could be high: species that require duff would be restricted to shrinking areas and could eventually disappear. Some common species of great ecological and economic importance, such as sugar maple, could become difficult to regenerate, favoring less susceptible species, such as those that favor mineral soil, leading to major shifts in plant communities.

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Metadata
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11/29/1022

Sean Dunlap entered points from the 2003 and 2004 worm surveys into a GIS layer, along with stand-level information for Mud Lake, Ridge, Rousseau, and Beaton VMPs. He either entered these as points or converted the botany survey stands to centroids later to match the worm survey points. Sue Trull added stands found to contain worms in MIS surveys (2006-2011); Redboat (2008 Wernerehl and Mason contractors; 2011 Dube contractor and Trull stands); and points from Delich LX and federal minerals surveys (not all of them). Other data not yet available: Ian Shackleford's additional stands in Beaton (2010 and 2011) and in Redboat 2011. Trull converted the stands to centroids using Xtools to generate Fig. 2.

Shapefiles are filed in T:\FS\NFS\Ottawa\Program\2900InvasiveSpecie\GIS\ExoticSpeciesGIS; one as "earthworm_survey_sites" and one as "DocumentedWormed 20111129Trull".
"WormStandsAdded2011Trull " provides a current (as of Nov. 2011) Forest stand layer for editing to add information to the last three columns for worming (as Y = yes, L = low, M = medium, H= high); source (name of survey) and year of observation.